

OVER CURRENT PROTECTION RELAY USING PIC MICRO CONTROLLER

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CHAPTER 1

INTRODUCTION

1.1 Background

Electrical Power System protection is required for protection of both user and the system equipment itself from fault, hence electrical power system is not allowed to operate without any protection devices installed. Power System fault is defined as undesirable condition that occurs in the power system. These undesirable conditions such as short circuit, current leakage, ground short, over current and over voltage.

With the increasing loads, voltages and short-circuit duty in distribution system, over current protection has become more important today. The ability of protection system is demanded not only for economic reason but also consumers just expect 'reliable' service. In a Power System Protection, the system engineer would need to a device that can monitor current, voltage, frequency and in some case over power in the system. Thus a device called Protective Relay is created to serve the purpose. The protective relay is most often relay coupled with Circuit Breaker such that it can isolate the abnormal condition in the system. In the interest of reliable and effective protection, some designers of power distribution/power controllers select relay as opposed to electro-magnetic circuit breakers as a method of circuit protection.

1.2 Overview of Over Current Relay Project

An "Over Current Relay" is a type of protective relay which operates when the load current exceeds a preset value. In a typical application the over current relay is used for over current protection, connected to a current transformer and calibrated to operate at or above a specific current level.

This project will attempt to design and fabricate over current protection relay using PIC micro controller. The PIC micro controller will cause the circuit breaker to trip when the current from load current reaches the setting value in the PIC micro controller.

In order to design it, first the load current need to measure in order to monitor it using current sensor including testing the fault (over current) and when such condition arise, it will isolate in the shortest time possible without harming the any other electrical devices. It will also including in developing the algorithm for instantaneous over current relay and IDMT (Inverse Definite Minimum Time) relay for the circuit breaker to trip. In this project, PIC microcontroller will be used to control and operate the tripping coil in circuit breaker.

1.3 Objective

The objectives of this project are;

- I. To design and fabricate over current protection relay using PIC micro controller which can operate on the permissible conditions by setting the over current value.
- II. To test unwanted conditions (over current) and when such conditions arise to isolate the fault condition in the shortest time possible.
- III. To investigate IDMT curve characteristic.

1.4 Scope of Project

The scopes of the project are;

- i. To measure and analyze load current from current sensor.
 - The load current (energizing current) will be measured by using current sensor and converted from analog voltage to digital using PIC16F877A. Then the load current will display on the LCD.
- ii. Trip circuit breaker using PIC microcontroller.
 - The over current value is set in the PIC and when faults (over current) occur, PIC will energize the circuit breaker tripping coil which will cause the circuit breaker to trip.
- iii. Develop algorithm for instantaneous over current relay and IDMT relay.
 - The over current setting may be given by definite time or inverse definite minimum time (IDMT) characteristic. There are four curves for over current complying with the IEC 255 and are named 'Normal Inverse', 'Very Inverse', 'Extremely Inverse' and 'Long Time Inverse'. This project is to develop the 'Long time Inverse' characteristic of IDMT.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Introduction

This chapter will discuss the study about significant parts of protection system such as the important of protection system, protection devices, types of protection system and protection relay. It also includes the PIC Microcontroller which is ‘the brain’ for this over current protection relay.

2.2 What Is Over Current

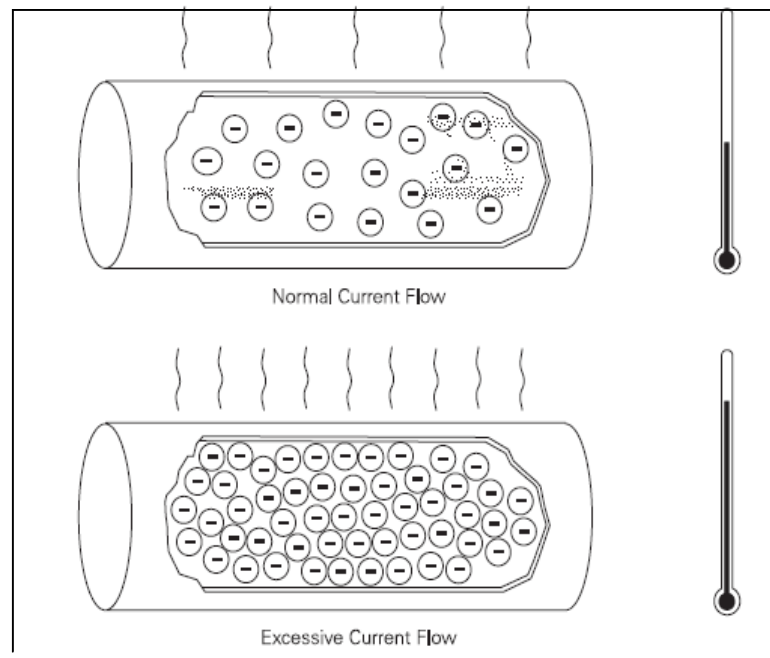


Figure 2.1: Over Current Flow

The National Electrical Code defines over current as any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. Current flow in a conductor always generates heat. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Over current protection devices are used to protect conductors from excessive current flow. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating [4].

2.3 Why Protection System Is Important

Fault impose hazard to both user and the system itself and when it comes to user, life is the concern and when it concern the system it is merely to provide stable electrical power system on top of that prevent damage to the expensive equipment used. In summary, the needs of power protection are [1]:

Table 2.1: Power System Protection Area

User/Personnel Safety	Prevent injury and accident.
Equipment	Safe guard the equipment from over current, over voltage and frequency drift that can cause damage
General Safety	Prevent secondary accident that result from power system fault such as fire
Power Supply Stability	Ensure that continuous and stable electrical power supplied by the system/grid
Operation Cost	Ensure that the system is operating at optimal efficiency and reduce equipment maintenance and replacement cost

Shock Phenomenon is almost similar to electrocution. High voltage above 500V can cause human skin rupture. The effect of this is the decrease of human body resistance. In certain condition, the resistance may drop down to about 500Ω. At 500V from Ohms law,

$I = V/R$ therefore,

$$I = 500/500 = 1A$$

Typically 16mA is considered hazardous to human. The following table shows the effect of current on human at 60Hz, AC. [2]

Table 2.2: Effect of Live Current on Human

Current	Effect on Human
1 mA	Barely perceptible
16 mA	Maximum current an average man can grasp and "let go"
20 mA	Paralysis of respiratory muscles
100 mA	Ventricular fibrillation threshold
2 Amps	Cardiac standstill and internal organ damage
15/20 Amps	Common fuse or breaker opens circuit

2.4 Power System Protection Devices

The idea of power protection system is to isolate the fault in the shortest time possible. Once fault occurs, the isolation part takes place by opening or disconnecting the circuit at the fault section. Almost all protection devices will act automatically when fault occurs but that doesn't mean it will protect the electrical equipments. Relay is the most common device that can actually serve the problems. Relay is a device which disconnects the circuit when there is input (to relay). Relay can be dividing into three major types;

- **Instantaneous (Instant reaction)**

Instantaneous over current protection is considered the simplest protection scheme. It is widely used because of its quick reaction time.

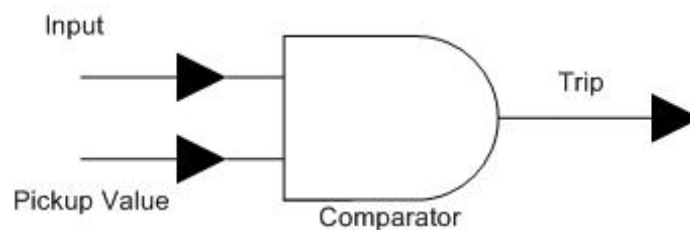


Figure 2.2: Logic diagram of instantaneous over current scheme

The relay pick up value is commonly set to a value anywhere between 125-135% of the maximum load current and 90% of the minimum fault current. These values help to minimize unnecessary responses from the relay. The Following formula is used to calculate the pick up value [5]:

$$1.2 \times \text{Max load current} \leq \text{Pick up value} \leq 0.9 \times \text{Min fault current} \quad [5]$$

- **Time Delay (Tripping will only occurs after certain settable time)**

There are two settings that must be applied to all time-delay over current relays: 1) the pickup value and 2) the time delay. Time relays over current are designed to produce high operation at high current slow operation at low current; hence, an inverse time characteristic. Relays from different manufactures may have different inverse time characteristics. In order to use these inverse time characteristics, you must first calculate the following:

$$\text{"Multiples of pickup values"} = \text{fault current} / \text{pick up value} \quad [5]$$

- **Numerical Relay (Static relay uses microprocessor and operate based on numerical method calculation)**

Numerical relay is a special type of digital relay that actually uses the capability of the modern microprocessor to actually calculate the fault value and perform analysis such as Fourier Analysis on the fault data before even making decision to trip the system or not. Numerical Relay also usually has the capability to record the faults value for analysis. Most often these relays are also equipped with communication port that allow maintainer to download information form the relay after the fault has occurs or just for system health analysis purposes [2].



Figure 2.3: Types of protection relay

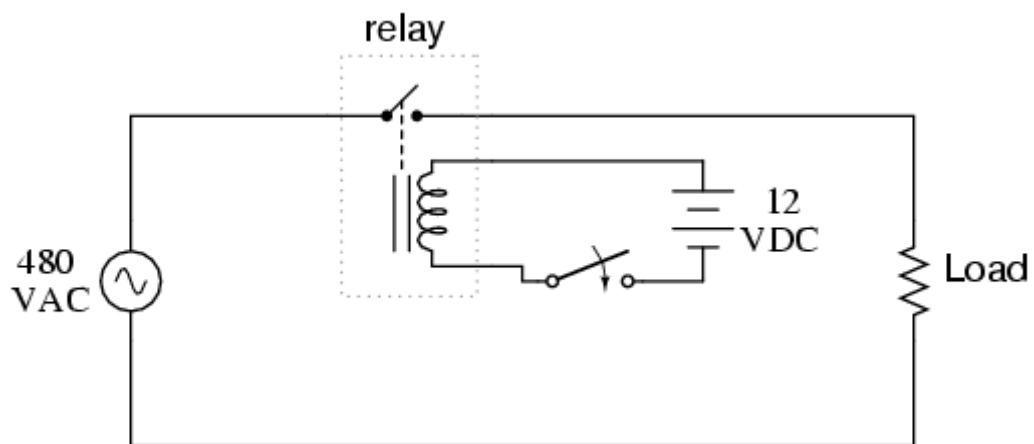


Figure 2.4: Basic principle operation of a relay

Figure 2.3 shows the basic principle of a relay and how it would be used in electrical circuit. The high voltage is connected to the load via the relay such that automatic disconnection of the load can happen in the case of fault occurrences.

Relay is a passive device that can only be ON or OFF state by default. As such it does not actually know if when it should start to operate and when it should not. Active device that can actually “see” or sense the fault is required to instruct the relay on what to do. These devices are then connected to the relay input to make a mini protection scheme that can actually monitor faults and take necessary action.

To be able to do a good job, the protection scheme should be able to eliminate the fault condition on the smallest portion of the circuit in the shortest time possible. [2]

2.5 Types of Protection System

Power protection system can be implemented into two ways which are ‘non-unit schemes’ and ‘unit schemes’.

2.5.1 Non-Unit Protection

The Non-Unit protection scheme work on the system and it might overlap with another protection device in the systems. The use of this mode of protection is usually to isolate the whole circuit when a fault occurs. [2]

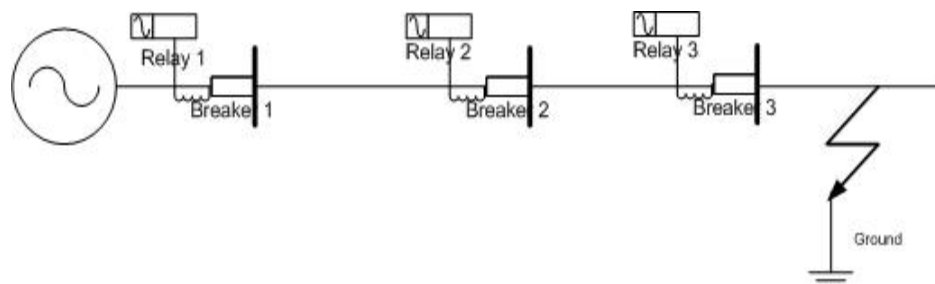


Figure 2.5: One line diagram typical non-unit protection

There are three protection relays installed in this system for the protection. If instantaneous relay is use, fault occurring at 3 will cause the whole system to trip because relay 1 and 2 also can see the fault. If IDMT (Inverse Definite Minimum Time) is use, the relay will isolate in the smallest section which in 3. Note that relay at 2 will trigger after several settable times and take over (isolate) the fault if relay at 3 fail to isolate the fault. The advantage of this system is it has the backup capability and it guarantee that the fault will be removed by at least one of the protection relay.

2.5.2 Unit Protection

The main purpose of the unit protection scheme is to protect a defined or discrete zone of location that is usually the zone bounded by the 2CT used for differential current measurement. Relay used in Unit Protection scheme are usually Differential Protection relay [2]. The protection system should be designed to satisfy the following requirements:

- 1) Under normal conditions the breakers are not tripped
- 2) Under fault conditions only the breaker closest to the fault will trip
- 3) If the closest breaker fails to operate, then the next breaker closest to the fault will trip [5].

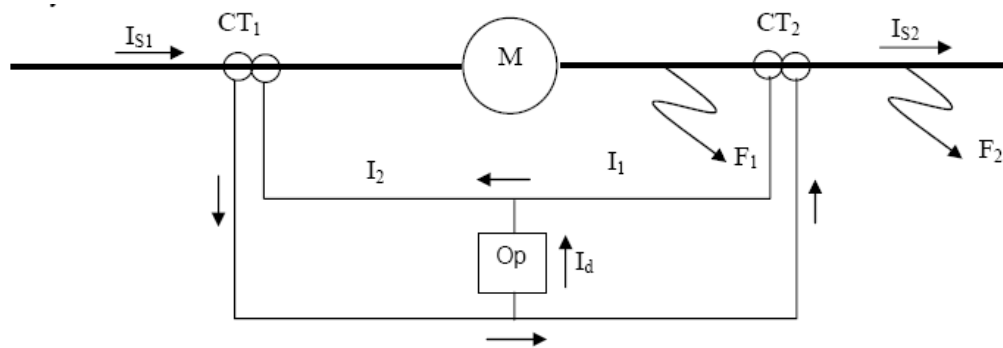


Figure 2.6: Differential fault current measurement

The figure above shows the operation of a unit protection. The two CT is used to measure the incoming and outgoing current into the protected load M. Under normal operating condition, I_{S1} will be equal to I_{S2} , therefore, $I_1 = I_2$, thus result in $I_d=0$. However, when $I_1 \neq I_2$ (Fault at F1), then I_d will have the value of I_1-I_2 . The current is then detected by the relay that will then cause trip in the system. For this protection scheme, if the fault occurs at F2, the protection system will not be able to detect the fault because it is happening outside the protection zone of the system.



Figure 2.7: Type SPAJ 140C Over current and Earth Fault Relay

2.5.3 Inverse Time Over current Protection

In a system for which the fault current is practically determined by the fault location, without being substantially affected by changes in the power source impedance, it is advantageous to use inverse definite minimum time (IDMT) over current protection. This protection provides reasonably fast tripping, even at a terminal close to the power source where the most severe faults can occur [8].

The inverse time over current protection elements have the IDMT characteristics defined by equation;

$$t = TMS \times \left\{ \left[\frac{k}{\left(\frac{I}{I_s} \right)^a - 1} \right] + c \right\}$$

Where:

t = operating time for constant current I (seconds),

I = energizing current (amps),

I_s = over current setting (amps),

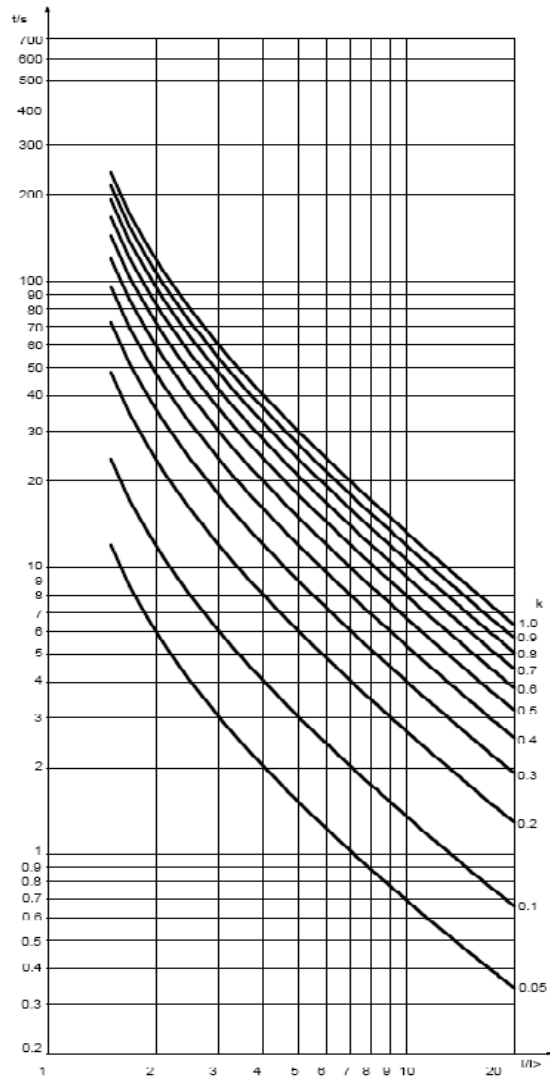
TMS = time multiplier setting,

k, a, c = constants defining curve.

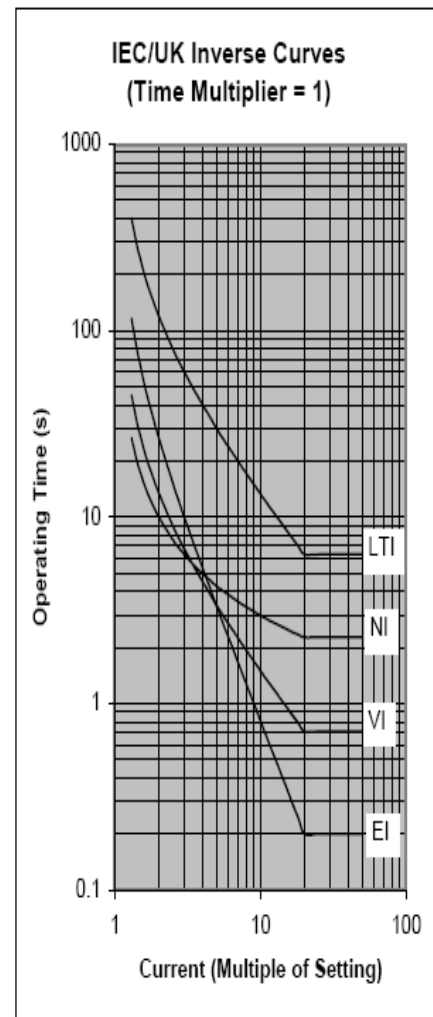
Four curve types are available as defined in Table 2.3. They are illustrated in Figure below.

Table 2.3: Specification of IDMT Curves

Curve Description	k	a	c
IEC Normal Inverse (NI)	0.14	0.02	0
IEC Very Inverse (VI)	13.5	1	0
IEC Extremely Inverse (EI)	80	2	0
IEC/UK Long Time Inverse (LTI)	120	1	0



(a)



(b)

Figure 2.8: Figure (a) shows that the 'Long Time Inverse' characteristic and (b) is types of IDMT Characteristic

2.6 ‘The Brain’

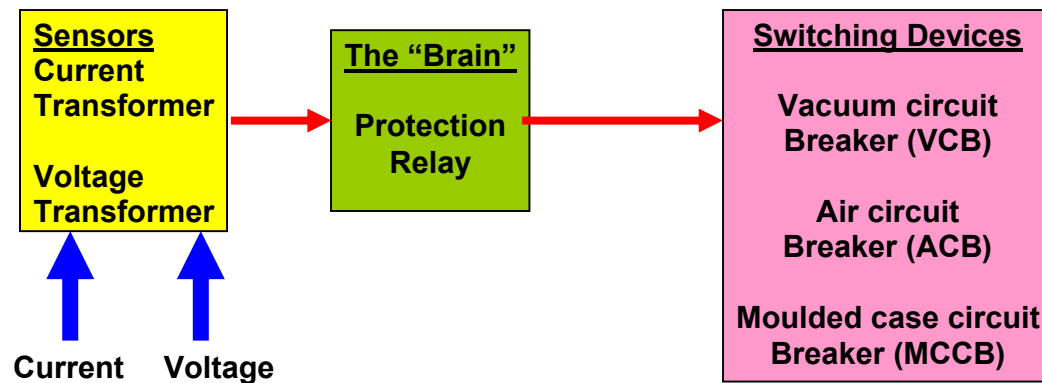


Figure 2.9: Building block of protection system

The block diagram above shows the protection system flow. Protection system is mainly controlled by the protection relay which is the brain of the protection system. Current transformer/voltage transformer will drop voltage/current in secondary windings. If there are over current/over load, the protection relay will open the circuit (cut-off) and cause the switching devices to trip. Protection relay play an important role in this system to cause the circuit breaker to trip and it can be implemented at various stages and various types of protection devices. Most of all, the protection relay only act as the brain of the protection and actual switching work are done by the circuit breakers and isolators.

2.7 PIC Micro Controller

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1640 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to

"Programmable Interface Controller", but shortly thereafter was renamed "Programmable Intelligent Computer".

PICs are popular with developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability [7].

PIC microcontrollers are frequently used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools, and toys. By reducing the size, cost, and power consumption compared to a design using a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to electronically control many more electrical and mechanical devices [6].

To summarize, a microcontroller contains (in one chip) two or more of the following elements in order of importance [8]:

- i. Includes Powerful Microchip PIC16F877 Microcontroller with 8kb
Internal Flash program memory
- ii. Operating Speed at 10MHz
- iii. Direct In-Circuit Programming for Easy Program Updates
- iv. Up to 28 I/O points with easy to connect standard headers
- v. Internal EEPROM
- vi. 8 Channel 10-bit A/D Converter
- vii. One 16-bit Timer with Two 8-bit Timers
- viii. Serial port
- ix. Reset Button

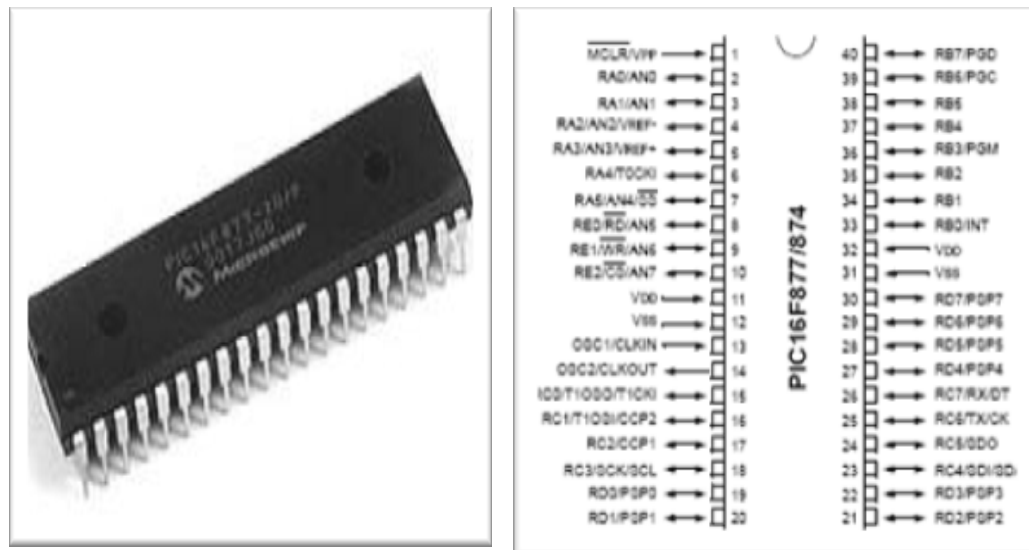


Figure 2.10: PIC 16F877A and its Schematic

2.8 Summarization

Power system protection is a very important element in electrical field and it is required to protect equipments as well as human. This chapter is likely to approach the review about important part in the electrical protection system which is over current protection relay. Over current protection relay which utilize with microprocessor and is based on the most advanced digital technology, is now widely used to protect lines, generators, transmission and motors. To develop this project, the knowledge about the controller which is ‘the brain’ for this system is very important. This project will use PIC micro controller as the processor. Though, the result of this project should have the basic operation and principles of over current relay.

CHAPTER 3

METHODOLOGY AND DESIGN

3.1 Introduction

This chapter explains how to design the over current relay including hardware and software implementation. This chapter also will cover about designing the basic PIC circuit, keypad and LCD, current sensor circuit, interfacing PIC to circuit breaker and PIC programming.

Before looking the details of designing this project, it is best to start with brief review of the system design. Figure 3.1 shows the complete system design of over current relay.

3.2 System Design

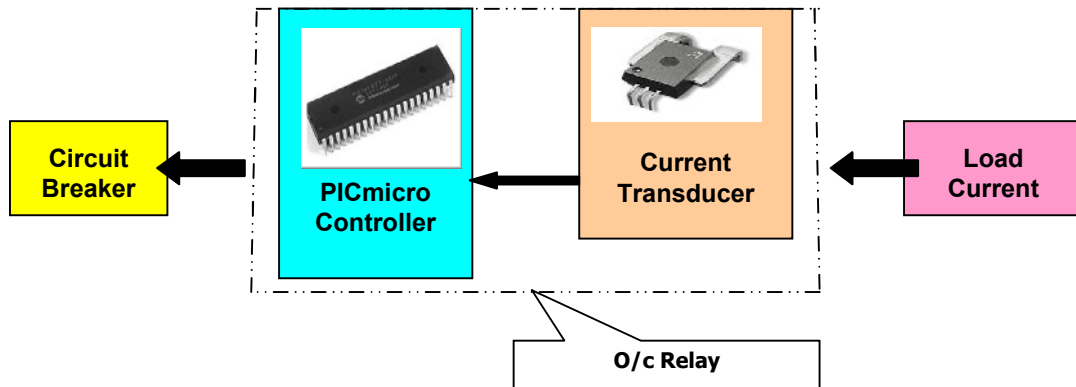


Figure 3.1: Block diagram of the system

The whole idea of this project is to isolate the faulty conditions from the load current by controlling the circuit breaker tripping coil using PIC micro controller. When there are over current at the bus bar (load current), current transformer will supply the reduced current to current sensor.

Current sensor will be used to measure the load current and will convert this current to certain voltage level as an input to microcontroller. Microcontroller will process and compare this voltage with desired voltage setting and will operate the tripping coil in circuit breaker if input voltage reaches the setting value.

3.3 Main Components

3.3.1 Current Transformer

Current Transformers (CT's) are instrument transformers that are used to supply a reduced value of current from bus bar or cables to meters, protective relays, sensors, and other instruments. CT's provide isolation from the high current primary, permit grounding of the secondary for safety, and step-down the magnitude of the measured current to a value that can be safely handled by the instruments.

CT ratios are expressed as a ratio of the rated primary current to the rated secondary current. For example, a 300:5 CT will produce 5 amps of secondary current when 300 amps flow through the primary. As the primary current changes the secondary current will vary accordingly. With 150 amps through the 300 amp rated primary, the secondary current will be 2.5 amps ($150:300 = 2.5:5$).

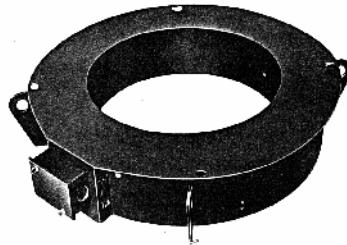


Figure 3.2: Current transformer

3.3.2 Current Sensor

Current sensor is a device, usually electrical, electronic, electro-mechanical, electromagnetic, photonic, or photovoltaic that converts one type of energy (current) or physical attribute to another (voltage) for various purposes including measurement or information transfer. In this project, current sensor will be used to

induce current from current transformer to certain voltage level as an input to PIC micro controller.

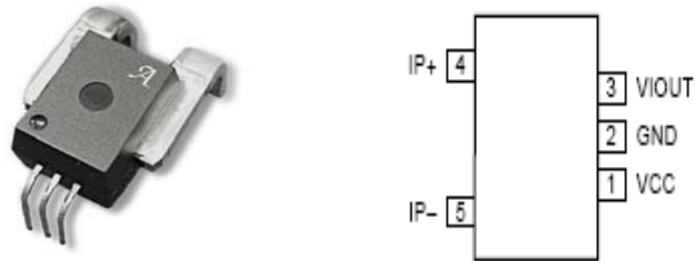


Figure 3.3: Current sensor types ACS754LCB-050-PFF.

Figure 3.3 show that the current sensor used in this project which is to measure the load current from current transformer. The Allegro ACS75x family of current sensors provides economical and precise solutions for current sensing in industrial, automotive, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, power supplies, and over current fault protection.

The device consists of a precision, low-offset linear Hall sensor circuit with a copper conduction path located near the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy at the factory.

This current sensor will measure the maximum current 50A from load current as its primary nominal current (I_{pn}). The output voltage, V_{out} ($1\text{mA}=40\text{mV}$) which is connected to the PIC micro controller as an analog.

Features and benefits:

- Monolithic Hall IC for high reliability
- Single +5 V supply
- 3 kVRMS isolation voltage between terminals 4/5 and pins 1/2/3 for up to 1 minute
- 35 kHz bandwidth
- Automotive temperature range
- End-of-line factory-trimmed for gain and offset
- Ultra-low power loss: $100\ \mu\Omega$ internal conductor resistance
- Ratiometric output from supply voltage
- Extremely stable output offset voltage
- Small package size, with easy mounting capability
- Output proportional to AC and DC currents

3.3.3 Circuit Breaker

A circuit breaker as a device designed to open and close a circuit by no automatic means, and to open the circuit automatically on a predetermined over current without damage to itself when properly applied within its rating. In addition, circuit breakers provide automatic over current protection of a circuit. Every circuit breaker has a specific ampere, voltage, and fault current interruption rating. The ampere rating defines the maximum current a circuit breaker can carry without tripping and normally residential circuit breakers are available with ratings from 10-

125 amps. The short circuit current should be of the order of around 200 A or higher for normal 10 A or 16 A ratings outlet to guarantee that the normal wire protecting fuse or breaker will quickly disconnect the supply in case of short circuit. The ratings of the circuit breaker depend on networks installed. The larger network the larger ratings.



Figure 3.4: Allen-Bradley circuit breaker with shunt trip coil

When supplying a branch circuit with more than one live conductor, each live conductor must be protected by a breaker pole. These may either contain two or three tripping mechanisms within one case, or for small breakers, may externally tie the poles together via their operating handles. Two pole common trip breakers are common on 120/240 volt systems where 240 volt loads (including major appliances or further distribution boards) span the two live wires. Three pole common trip breakers are typically used to supply three phase power to large motors or further distribution boards.

3.4 Hardware Implementation

This section will discuss about components that have been used in this project included basic PIC circuit, 5V supply, keypad & LCD, PIC interfacing with circuit breaker and current sensor circuit.

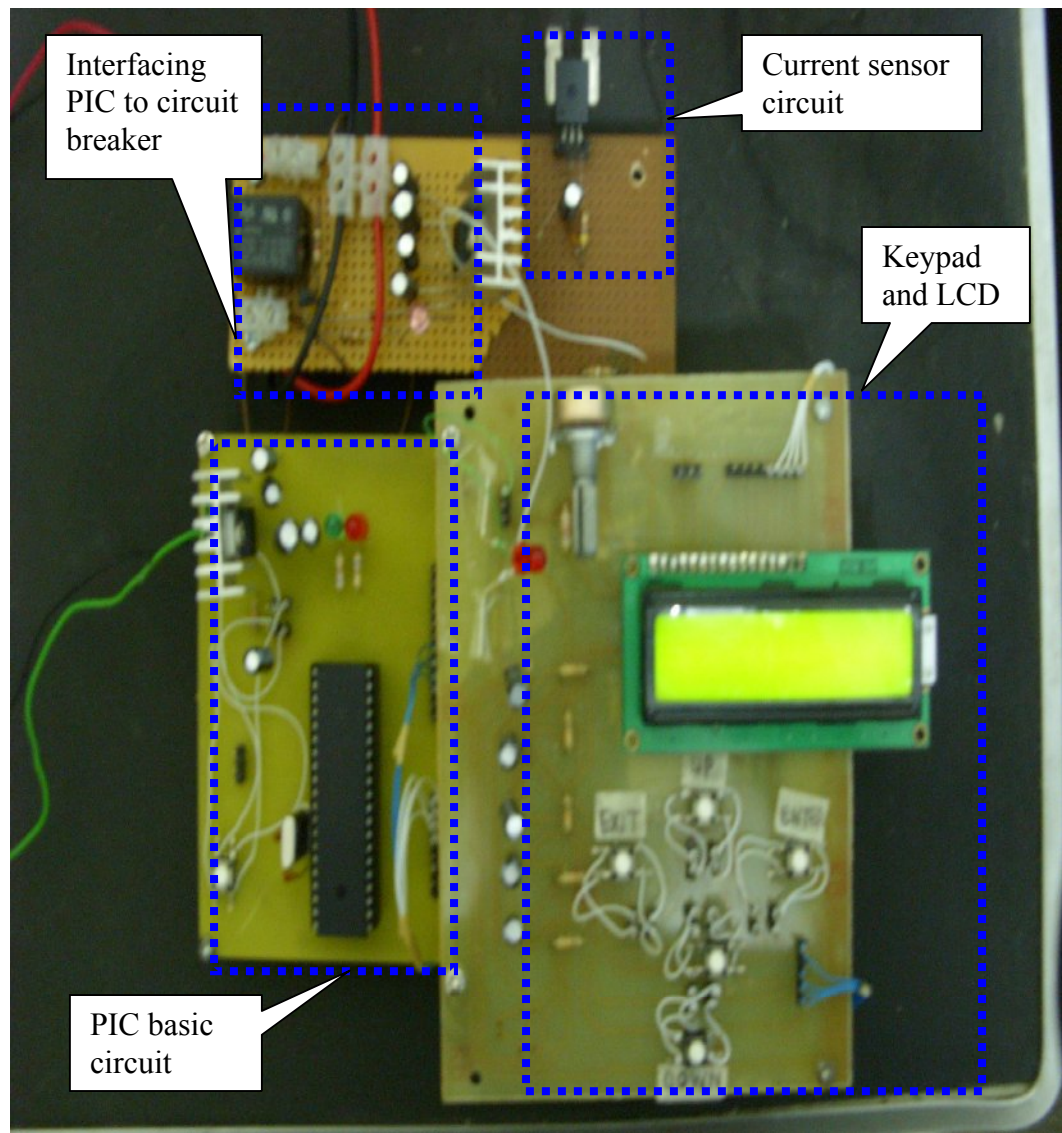


Figure 3.5: Full picture of hardware